A STUDY OF THE ECTOPARASITES OF VULPES FULVA IN NORTHWEST ILLINOIS

A Thesis

Presented to

The School of Graduate Studies

Drake University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

---

by

Spencer J. Artman

August 1969

A STUDY OF THE ECTOPARASITES OF VULPES FULVA IN NORTHWEST ILLINOIS

by

Spencer J. Artman

Approved by Committee:

Rodney A Rogers
Chairman

Stephen C. Elliott

B. Wendell Barnes

Earle L. Canfield
Dean of the School of Graduate Studies

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The study of population size and growth curves has been of great importance to biologists in recent years. These two phenomena play an important role in the understanding of ecological relationships. Scientists who have understood the ecology of organisms have made important contributions to society. The scientist who experiments to find a cure for a disease must first understand the ecological relationships of the pathogen and host involved. Likewise, the conservationist also must understand this concept if he is to assist in keeping life forces in balance.

Few studies have been reported concerning the ectoparasites found on the red fox. Available publications have listed the species of parasites found on the red fox, but do not list any information about the frequency of infection or transmission modes. Jackson (1961) classified the red fox found in Southern Wisconsin and Northern Illinois as Vulpes fulva fulva Desmarest. The purpose of this investigation was to ascertain the frequency of infection and modes of transmission of the ectoparasites found on this animal.

Fichter and Williams (1967) stated that the red fox has been present in North America for the past 14,000 years. They based their information on skeletal remains taken in archaeological excavations.

The birth of the red fox occurs between March 10 and April 20 after developing in the uterus for fifty-three days. This process of birth takes place in a den that has been enlarged by the female. Foxes often take over burrows made by woodchucks and other digging animals. The den is fifteen to thirty feet long with side compartments and is at least three feet below the surface of the ground (Jackson, 1961). The young foxes are blind for nine days after birth. Naaktgeboren (1965) commented that the litter consisted of four to five pups as an average. However, he stated that up to fifteen cubs have been found in one den.

After eight weeks the female weens the young, and both parents bring solid foods procured in nature. Partial remains of rabbits, pheasants, owls, ducks, chickens, and young pigs have been seen on and in the dens. Scott (1942) stated that the primary food supply of the red fox is directly related to the food available. However, the majority of food taken is mice of the genera Peromyscus and Micustus. The ability of the fox to catch his prey is related directly to his sense of hearing. This sense has priority over sight and smell (Osterholm, 1964). Since small rodents do not suffice during the raising of the young, the adults have to predate on larger specimens. Various farmers have described the decrease in their chicken and waterfowl populations during the months when the young foxes were being fed.

Besadny (1964) collected over 1,431 fox stomachs during the years 1955-1962 in Southeast Wisconsin. He stated that 90% of the food in the summer and fall was mice and rabbits. During these years 35% of the stomachs contained rabbits. However, in 1960-1961 only 18% of the stomachs contained rabbit remains. Rabbits were not available in excess during that year due to the severe winter. Meadow mice and deer mice showed up 44% of the time during his four year study. Scott and Klimstra (1955) conducted stomach analyses for three years and found that mammal remnants composed the highest percentage of materials found in these stomachs. Jackson (1961) stated that 60% of the stomach analyses during the winter months showed rabbits. A fox is capable of eating an entire rabbit at one feeding (Besadny, 1964). Eight foxes, each with a rabbit in possession, were seen during this three year study. This is a small percentage since the total foxes seen was 218. However, this was information gained during the first hour after sunrise, and it seems feasible that rabbits would be taken during the dark hours as well. Scott (1942) also demonstrated that more cottontails were taken during the winter and spring seasons.

The fox is apparently at ease with his environment. Fichter and Williams (1967) stated that the red fox has become more abundant since 1960 in Idaho. Jackson (1961) indicated the top abundance of foxes seems to be cyclic with high peaks reached about every ten years. These

peaks were reached in 1915, 1925, 1936, 1945 and 1953. Since 1944-1945 the abundance of foxes has remained at a relatively high, stable level (Richards and Hine, 1953).

In late December and during January the female begins her estrus cycle. Naaktgeboren (1965) indicated that the heat characteristics of the female include enlargement of the vulva, reddish colored labia, and a raising of the tail. Foxes have a definite courtship behavior and come into close contact with each other during this courtship period. This may be an important aspect of ectoparasite exchange. Sometime during the first year of life, the fox becomes parasitized by fleas.

The coxa of the three pair of legs gives the flea great jumping ability, and this enables the flea to travel quickly to various parts of the host's body or to other hosts. Complete metamorphosis in the flea's life cycle may act as a means of transmission to a host. The pupa stage often emerges due to vibrations transmitted to the cocoon. Thus, the pupa stage may remain dormant until the host returns to the den or nest. This has a definite advantage in the survival possibilities of the various species of fleas (Noble and Noble, 1965).

Host specificity is not extremely strong in the Siphonaptera since the flea's chances of finding a specific host upon emerging from a cocoon is slight. Thus, a given species of flea might often be found on several hosts. The origin of mammal fleas is obscure. Many mammals are carnivores, and the mammal flea could

have first evolved by transfer from another animal host.

A great deal of research has been carried out on the Siphonaptera. Much of this research centers around the rabbit flea Spilopsyllus cuniculi Dale. This flea's reproductive cycle is coordinated with that of the rabbit. The ovaries develop at the time of parturition in the rabbit, and the fleas travel to the nestlings to copulate and deposite eggs (Mead-Briggs, 1964).

Rothschild (1964) isolated the hormone that caused the reproductive system of the flea to activate and stated that it was produced in the anterior lobe of the pituitary gland of the rabbit. The first signs of ovary maturation was an increased defecation rate by the fleas.

Later, Rothschild (1965) found that corticosteroids controlled maturation and the estrogens played an important part in the development and egg laying of the flea. Finally, he was able to prove that LH and the progestins in the rabbit's blood caused ovarian regression in the flea, and that somatotropin caused ovulation (Rothschild, 1966).

These experiments, described above, deal with only one species of flea. However, this concept may play an important role in the physiology of other fleas.

Mead-Briggs (1964) has shown that fleas tend to have great ability to find their host. In his experiments he found that fleas would transfer to other rabbits. He further showed that when fifty groups, each of four to six fleas, were distributed over a pasture so that their

density was one group per 360 square feet, 45% of the fleas could be recovered by the use of only three rabbits. He also demonstrated that a female host proved to be more desirable than a male.

Stark (1962) showed that fleas tended to leave a host that was in a state of excitement. While working with fleas on Micustus, two-thirds left the host in three to five minutes. These various experiments will be important in the interpretation of the data collected in this investigation.

There is no available material correlating the frequency of infection of flea species found on the red fox. There are a few reports in which authors have examined a fox and then identified the species found. Wilson (1966) listed hosts for Pulex simulans and included Vulpes fulva fulva as a host. Fox (1940) described the following species found on the red fox; Ctenocephalides canis Curtis, Hoplopsyllus affinis Baker, Pulex irritans Linnaeus, Cediopsylla simplex Baker, Oropsylla aretomys Baker, Megabothris wagneri Baker, Echidnophaga gallinaceae Westwood, and Epitedia wenmanni Rothschild. Jackson (1961) also listed these fleas on Vulpes fulva fulva.

Since there is still important information to be gained about the ectoparasites of the red fox, this study was designed to identify species of fleas, determine the infection rates on male and female foxes, and to ascertain the mode of transmission of these fleas to the foxes.

MATERIALS AND METHODS

To correlate the frequency of infection, adult red foxes were collected for a three year period during the months of November through February. Foxes were obtained by the technique of hunting. The various methods employed consisted of road spotting, calling, and organized hunts.

Road spotting was a method that allowed a large area of land to be covered in a relatively short time. The basic items needed to conduct this operation were 10 X 50 binoculars, an automobile, and a high powered rifle. Storm (1965) described the movements and activities of foxes as measured by radiotracking. He pointed out that foxes tended to prefer a grain field as a place to sleep during the day hours. In winter the foxes tended to sleep on south banks of hay fields or on snow drifts in highly elevated sections. By driving on the gravel roads that permitted a good view of south sloping fields, foxes could be spotted with the binoculars. High vantage points were used effectively in spotting. The technique for sighting these foxes developed with experience in looking at the same areas repeatedly each day. Often the foxes would select a snow drift on which they would bed down. Seldom was a fox seen close to the road. They normally would be 600 to 1,000 yards away, and a pair of binoculars of sufficient magnification was necessary to spot them.

Once the fox had been sighted, correct procedure

had to be utilized to get close enough to secure a good shot. A white parka was beneficial since it blended with the snow, and stalking was done against the wind. The rifle used for the study had certain specifications. It had a good variable power scope, and the bullet had a flat, fast trajectory which insured less chance of ricochet.

Both the rifle and shotgun were utilized in the technique of fox calling. Morse and Balser (1961) conducted a study on the effectiveness of this method. A call was used that resembled a rabbit in distress. These calls had a range limit of less than one-half mile and thus, the hunter had to select an advantageous vantage point in the middle of a section. He had to be concealed and high enough to see the surrounding country side. The results of their experimentation showed that the hunter, when proficient, could expect 14.4% success. The caller obtained best results by calling six to twelve harsh distress calls at intervals of thirty to ninety seconds for fifteen minutes. Eighty-four percent of the foxes responded to the distress calls within fifteen minutes.

Group hunting was done with shotguns. Approximately sixteen hunters were needed in this operation. Four hunters entered each of the four sides of a section and forced any foxes therein to the other hunters. This technique, as well as fox calling, was time consuming and fewer foxes were collected as compared to those collected by road spotting.

As soon as any foxes were killed, they were

immediately placed in a plastic bag. This insured that the fleas, if present, would not escape. At the end of the hunt, the foxes were examined. Approximately four hours after death, the bodies had cooled enough that the fleas had traveled to the surface of the fur. Most fleas were secured by this phenomenon. However, some fleas were collected from the plastic bag, and remaining fleas were obtained by combing the fur. To check for thoroughness, a final technique was employed. Hopwood (1965) illustrated that fleas would leave a host if a piece of cotton that had been saturated with chloroform was placed in a plastic bag with the mammal specimen. This technique was employed but without results. All the fleas had left the foxes previous to the chloroform treatment.

The fleas were placed in a collecting bottle containing 70% ethanol. To prepare the fleas for identification, the following procedure as described by Hubbard (1968) was employed. The fleas were bleached by placing them in a 10% solution of sodium hydroxide. The light pigmented fleas bleached in 18 to 24 hours. At this time the abdominal viscera was no longer apparent. The darker pigmented fleas required 24 to 36 hours and at times, heat from a 100 watt light bulb was required to obtain the desired bleaching within the time interval. Next, the fleas were placed in a 1% acetic acid solution to neutralize the base used previously. Then, they were run through a series of alcohols: 25%, 50%, 75% and 96% ethyl alcohol for three hours each. To clear the

specimens, carbol-xylol was used. After three hours the fleas were placed in cedar oil and then into xylene. The permanent slides were made with the use of canada balsam.

Identification was based on the classification as reported in Fleas of Western North America, Fleas of Eastern United States, and by Dr. R.E. Lewis.

The mode of transmission of fleas was investigated by two methods. Young foxes were collected during the month of May, 1969. By writing an article in the local newspaper requesting help from local farmers, the location of dens that contained litters of foxes was obtained. Storm (1965) described the technique of using a wire ferret to collect foxes. The ferret was made of 4mm spring steel wire and was 35 feet in length. One end was wound into a coiled spring, and the other end was bent into a L-shape. Since the use of a wire ferret was outlawed in Illinois, a collectors permit was secured through the Illinois State Conservation Department. This method of using the ferret consisted of winding it into the den and as the young foxes ran out, they were caught with a fisherman's dip net. Occasionally, the pups would get entangled in the coiled spring and could be pulled out carefully.

Once captured, the foxes were treated to remove all fleas. The technique used consisted of washing the foxes with a strong detergent, and then using the chloroform method. Next, the young foxes were ear tagged and placed

into a pen. The investigation was to be conducted in the following manner. A control group of ten foxes was to be fed on dogfood. The experimental group of ten foxes would be fed on wild mice and rabbits. By checking the foxes at a later date, potential parasite transfer from the natural food to the foxes could be checked.

Another method used to correlate the mode of transmission consisted of checking the species of fleas found on the foxes with those found on their natural food supply. Layne (1958) and Verts (1961) listed the species of fleas found on mammals in Illinois. Fleas of Western North America also proved to be an important reference.

DATA AND DISCUSSION

During the three year study 107 foxes were collected. Of these, 74 were placed in plastic bags immediately after their death and were checked for fleas. Sixty-three percent of the foxes were males and over 90% of all the foxes collected were obtained in Stephenson County, Illinois. Fleas were found on 60.5% of the foxes and 65% of the fleas present were on the female foxes. There appears to be more foxes with both sexes of a flea species present during the month of January. A greater percentage of fleas was found on the foxes that had been killed by the rifle. This data has been summarized in tables 1, 2, and 3.

Fox 58 was suffering from mange and identification of the causal organism was made by the College of Veterinary Medicine at Urbana, Illinois. The pathogenic

Table 1. Foxes shot in 1966-1967 and fleas present.

Fox Host	Sex	Date	Location	Weapon	Total Fleas
1	Male	12/66	Jo Davis	Shotgun	4
2	Female	12/66	Jo Davis	Shotgun	3
3	Male	12/66	Stephenson	Shotgun	2
4	Female	12/66	Stephenson	Shotgun	5
5	Female	12/66	Stephenson	Shotgun	0
6	Male	12/66	Stephenson	Shotgun	3
7	Male	12/66	Stephenson	Shotgun	0
8	Male	12/66	Stephenson	Shotgun	0
9	Male	12/66	Stephenson	Shotgun	0
10	Male	12/66	Stephenson	Shotgun	3
11	Male	12/66	Stephenson	Shotgun	2
12	Male	12/66	Stephenson	Shotgun	0
13	Female	12/66	Stephenson	Shotgun	0
14	Female	1/67	Stephenson	Shotgun	7
15	Male	1/67	Stephenson	Shotgun	2
16	Female	1/67	Stephenson	Shotgun	3
17	Male	1/67	Stephenson	Shotgun	0
18	Male	1/67	Stephenson	Rifle	3
19	Female	1/67	Stephenson	Shotgun	4
20	Male	1/67	Stephenson	Shotgun	4
21	Male	1/67	Stephenson	Shotgun	2
22	Male	2/67	Stephenson	Shotgun	0
23	Male	2/67	Stephenson	Shotgun	0
24	Male	2/67	Stephenson	Shotgun	0

Table 2. Foxes shot in 1967-1968 and fleas present.

Fox Host	Sex	Date	Location	Weapon	Total Fleas
25	Male	12/67	Stephenson	Shotgun	0
26	Male	12/67	Stephenson	Shotgun	0
27	Male	12/67	Stephenson	Shotgun	0
28	Female	12/67	Stephenson	Shotgun	0
29	Male	12/67	Stephenson	Shotgun	2
30	Male	12/67	Stephenson	Rifle	3
31	Female	12/67	Stephenson	Rifle	2
32	Male	12/67	Stephenson	Shotgun	0
33	Male	1/68	Stephenson	Rifle	2
34	Male	1/68	Stephenson	Shotgun	1
35	Female	1/68	Carroll	Rifle	4
36	Male	1/68	Stephenson	Rifle	0
37	Male	1/68	Stephenson	Shotgun	1
38	Female	1/68	Stephenson	Shotgun	2
39	Female	1/68	Stephenson	Shotgun	2
40	Male	1/68	Stephenson	Rifle	0
41	Female	1/68	Stephenson	Rifle	5
42	Female	1/68	Stephenson	Rifle	4
43	Male	1/68	Stephenson	Rifle	2
44	Male	1/68	Stephenson	Shotgun	0
45	Male	1/68	Stephenson	Shotgun	1
46	Male	1/68	Stephenson	Shotgun	1
47	Male	2/68	Stephenson	Shotgun	0

Table 3. Foxes shot in 1968-1969 and fleas present.

Fox Host	Sex	Date	Location	Weapon	Total Fleas
48	Female	11/68	Jo Davis	Rifle	1
49	Female	12/68	Stephenson	Shotgun	0
50	Female	12/68	Stephenson	Shotgun	1
51	Male	12/68	Stephenson	Shotgun	0
52	Male	12/68	Stephenson	Rifle	2
53	Male	12/68	Stephenson	Rifle	1
54	Male	12/68	Stephenson	Rifle	2
55	Female	12/68	Carroll	Rifle	4
56	Female	12/68	Carroll	Rifle	4
57	Male	12/68	Carroll	Rifle	0
58	Male	1/69	Stephenson	Rifle	0
59	Female	1/69	Stephenson	Rifle	5
60	Male	1/69	Stephenson	Rifle	4
61	Female	1/69	Stephenson	Rifle	5
62	Female	1/69	Stephenson	Rifle	4
63	Female	1/69	Stephenson	Rifle	5
64&65	Males	1/69	Stephenson	Rifle	0
66	Female	1/69	Stephenson	Rifle	4
67	Female	1/69	Stephenson	Rifle	7
68	Male	1/69	Stephenson	Rifle	0
69	Female	1/69	Stephenson	Rifle	7
70	Male	1/69	Stephenson	Rifle	0
71	Male	2/69	Stephenson	Rifle	3
72&74	Males	2/69	Stephenson	Rifle	0
73	Female	2/69	Stephenson	Rifle	2

mite was Sarcoptes scabiei (Ivens, 1969).

The species of fleas collected and their frequency of appearance is summarized in tables 4, 5, and 6. There were four different species of fleas present; Cediopsylla simplex Baker, Ctenocephalides canis Curtis, Epitedia wenmanni wenmanni Rothschild, and Chaetopsylla lotus Steward.

Cediopsylla simplex composed 57.5% of the total fleas present, followed by C. lotus with 41.4%, C. canis with 1.4%, and E. wenmanni wenmanni with 0.72%.

Cediopsylla simplex occurred in greatest numbers during the 1968-1969 collecting season. Of the 79 fleas of this species, 42 were collected then. During this season there were more snowfalls and extreme icy conditions as a result of freezing rains in contrast to the two previous winters.

The collection of young foxes used in an attempt to discover the mode of transmission of these fleas is summarized in table 7. Once collected and checked for fleas, the young foxes were placed in a pen. On May 15, 1969 one fox had died and several others showed symptoms of paralysis in the hind limbs. The stool specimens indicated the presence of coagulated blood. At this time, fox 9-1 (table 7) was taken to the Animal Veterinary Hospital. Upon conducting an autopsy, it was discovered that the fox's small intestine was highly parasitized by large numbers of ascarids, a few hookworms, and an excessive number of tapeworms. Use of a standard flotation technique conducted on a sample of a stool specimen

Table 4. Fleas on foxes that were shot in 1966-1967.

Fox Host	E. wenmanni wenmanni		C. lotus		C. simplex		C. canis	
	♀	♂	♀	♂	♀	♂	♀	♂
1	.	.	.	.	3	1	.	.
2	.	.	.	.	3	.	.	.
3	1	.	.	.	1	.	.	.
4	.	.	1	1	2	1	.	.
5	.	.	.	.	.	.	.	.
6	.	.	.	.	3	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	3	.	.	.	.	.
11	.	.	2	.	.	.	.	.
12	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.
14	.	.	5	.	2	.	.	.
15	.	.	1	1	.	.	.	.
16	.	.	1	.	2	.	.	.
17	.	.	.	.	.	.	.	.
18	.	.	2	.	1	.	.	.
19	.	.	2	.	2	.	.	.
20	.	.	2	1	.	.	1	.
21	.	.	1	1	.	.	.	.
22	.	.	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.
24	.	.	.	.	.	.	.	.

Table 5. Fleas on foxes that were shot in 1967-1968.

Fox Host	C. lotus ♀	C. lotus ♂	C. simplex ♀	C. simplex ♂
25	.	.	.	.
26	.	.	.	.
27	.	.	.	.
28	.	.	.	.
29	1	.	1	.
30	2	.	1	.
31	.	.	1	1
32	.	.	.	.
33	.	.	.	2
34	1	.	.	.
35	2	.	1	1
36	.	.	.	.
37	1	.	.	.
38	1	.	1	.
39	.	.	1	1
40	.	.	.	.
41	3	.	1	1
42	1	1	1	1
43	.	1	1	.
44	.	.	.	.
45	.	1	.	.
46	1	.	.	.
47	.	.	.	.

Table 6. Fleas on foxes that were shot in 1968-1969.

Fox Host	C. lotus ♀	C. lotus ♂	C. simplex ♀	C. simplex ♂	C. canis ♀	C. canis ♂
48	.	1	.	.	.	.
49	.	.	.	.	.	.
50	.	.	1	.	.	.
51	.	.	.	.	.	.
52	1	.	.	1	.	.
53	1	.	.	.	.	.
54	2	.	.	.	.	.
55	1	.	1	2	.	.
56	.	.	1	3	.	.
57&58	.	.	.	.	.	.
59	.	.	4	.	1	.
60	.	.	2	2	.	.
61	2	.	3	.	.	.
62	1	1	1	1	.	.
63	1	1	1	2	.	.
64&65	.	.	.	.	.	.
66	.	1	2	1	.	.
67	3	.	4	.	.	.
68	.	.	.	.	.	.
69	.	1	5	1	.	.
70	.	.	.	.	.	.
71	.	.	3	.	.	.
72&73	.	.	.	.	.	.
74	.	1	1	.	.	.

Table 7. Young foxes taken from dens.

Identification Number	Date Collected	Sex	Fleas
Fox 1-1[a]	4-30-68	Female	Absent
Fox 1-2	4-30-68	Male	Absent
Fox 2-1	5-2-68	Male	Absent
Fox 3-1	5-3-68	Male	Absent
Fox 3-2	5-3-68	Male	Absent
Fox 4-1	5-7-68	Female	Absent
Fox 4-2	5-7-68	Female	Absent
Fox 5-1	4-27-69	Male	Absent
Fox 5-2	4-27-69	Male	Absent
Fox 5-3	4-27-69	Male	Absent
Fox 6-1	4-28-69	Male	Absent
Fox 6-2	4-28-69	Female	Absent
Fox 6-3	4-28-69	Male	Absent
Fox 7-1	4-29-69	Female	Absent
Fox 7-2	4-29-69	Male	Absent
Fox 7-3	4-29-69	Male	Absent
Fox 7-4	4-29-69	Male	Absent
Fox 7-5	4-29-69	Male	Absent
Fox 8-1	4-29-69	Male	Absent
Fox 8-2	4-29-69	Male	Absent
Fox 9-1	5-1-69	Male	Absent
Fox 10-1	5-1-69	Male	Absent
Fox 10-2	5-1-69	Female	Absent

[a] First number of series represents den number and the second number identifies the fox from that den.

taken from the colon showed the presence of large numbers of Isospora oocysts. It was concluded that the combination of these parasites had caused death (Held, 1969). On May 16 eight more foxes died. The pen was thoroughly cleaned and scrubbed with detergent and four of the remaining foxes survived. At this point in the investigation, it was difficult to catch any more young foxes, since they were capable of running faster than the investigator. The remaining four foxes were fed on wild mice and rabbits for one week. These living food items were visibly infested with fleas. However, at the end of this week, no fleas were found on the four foxes.

Transmission of fleas to the foxes was also investigated by checking the fleas collected with those inhabiting the fox's food supply. Cediopsylla simplex is a rabbit flea and Hubbard (1968) reports taking as many as 200 specimens off a single cottontail. Chaetopsylla lotus is a flea found on mammals. Layne (1958) reports taking this flea off Urocyon c. cinereoargenteus (gray fox). Fox (1940) also lists this flea on the gray fox.

The interpretation of this data does answer part of the original problem, but also presents new problems. The observed frequency of infection varies with the seasonal conditions, the weapons used to obtain foxes, and with the species of fleas. Table 8 summarizes the overall ratio of fleas found on all foxes, on female foxes, and on male foxes. This table definitely

Table 8. Infection rates of fleas on foxes

	Total foxes	♂ foxes	♀ foxes
Foxes collected	74	47	27
Foxes infected with fleas	45	22	23
Percent of total foxes infected with fleas	60.5%	47%	85%
Foxes without fleas	29	25	4
Percent of total foxes without fleas	39.5%	53%	15%
Number of fleas on the foxes	140	51	89
Percent of the total fleas on foxes	100%	36%	64%
Average number of fleas on foxes parasitized	3.1	2.3	3.9
Infestation rate on each sex of fox		37%[a]	63%

[a] Calculations: $\frac{\text{Average number of fleas on } ♂ \text{ fox}}{\text{Sum of average number of fleas on the male and female foxes}}$

illustrates that the fleas show a preference to the female fox as a host. Mead-Briggs (1964) also found this phenomenon to be true in his research with the rabbit and Spilopsyllus cuniculi.

Tables 9 and 10 illustrate that a higher percentage of fleas could be collected from foxes that had been shot with a rifle. It seems feasible that this relates to the interval of time between being shot and the fox's death. Stark (1962) pointed out that fleas would tend to leave an excited host. Often, the foxes would travel several hundred yards before dying when shot with the shotgun. It is known that adrenalin is released into the blood stream of many animals during a time of excitement. It is possible that a chemical substance similar to adrenalin was released and initiated the flea's exit from the fox before he was placed into a plastic bag.

There was a definite increase in C. simplex numbers during the 1968-1969 collecting season. Scott (1942) proved that the fox's food supply directly related to its availability and more rabbits were taken by predation during the winter. Since there was an extreme amount of ice during the winter of 1968-1969, mice predation was probably inhibited due to the icy crust on the snow. Layne (1958) showed that C. simplex had the highest incidence on rabbits in Illinois. Of the 966 fleas taken from 14 hosts, 546 were C. simplex. Rabbits were the hosts for 544 of these fleas and two were found on the

Table 9. Infection rate of fleas on foxes correlated to fox death by shotgun.

	Total foxes	♂ foxes	♀ foxes
Foxes killed	38	26	12
Foxes infected with fleas	23	14	9
Percent of total foxes infected with fleas	60.5%	54%	75%
Foxes without fleas	15	12	3
Percent of total foxes without fleas	39.5%	46%	25%
Number of fleas on the foxes	55	28	27
Percent of the total fleas on foxes	100%	51%	49%
Average number of fleas on foxes parasitized	2.39	2.00	3.00
Infestation rate on each sex of fox		40%	60%

Table 10. Infection rate of fleas on foxes correlated to fox death by rifle.

	Total foxes	♂ foxes	♀ foxes
Foxes killed	36	21	15
Foxes infected with fleas	24	9	15
Percent of total foxes infected with fleas	66.7%	43%	100%
Foxes without fleas	12	12	0
Percent of total foxes without fleas	33.3%	57%	0%
Number of fleas on the foxes	85	22	63
Percent of the total fleas on foxes	100%	26%	74%
Average number of fleas on foxes parasitized	3.55	2.5	4.2
Infestation rate on each sex of fox		37.5%	62.5%

gray fox. Assuming that C. simplex transfers from the rabbits to the red foxes during predation, it is logical that the infection rate of C. simplex would have increased, and an increase was evident during the winter of 1968-1969.

Table 11 correlates the infection rates of E. wenmanni wenmanni and C. canis. Only one specimen of E. wenmanni wenmanni was observed. Fox (1940) and Jackson (1961) reported that this flea has been found on the red fox. Hubbard (1968) and Layne (1958) stated that this species is commonly found on Peromyscus m. bairdii. Transfer may occur during the red fox's predation on this species of mouse.

There was a higher percentage of female C. lotus in comparison with the sex ratio of C. simplex. Eighty percent of all C. lotus identified were females and 72% of C. simplex were females. Dr. Lewis (1969) has stated that this is common for both species. Due to the high incidence of Chaetopsylla lotus on the red foxes in Northwest Illinois, the foxes in this area may be one of the true hosts of this species of flea. The data summarizing infection rates of C. lotus and C. simplex is listed in tables 12 and 13.

Data on C. simplex indicates that of the four species identified, this flea has the highest incidence on foxes. There tends to be a greater incidence of both sexes of this flea on the foxes during January. Further research could possibly prove a relationship between the reproductive cycle of the female fox with that of this flea.

Table 11. Infection rates of red fox with *Epitedia wenmanni wenmanni* and *Ctenocephalides canis*.

1966-67	♂ foxes	♀ foxes	Total
Total foxes parasitized by *E. w. wenmanni*	0	1	1
E. w. wenmanni ♀ present	0	1	1
E. w. wenmanni ♂ present	0	0	0

1966-67	♂ foxes	♀ foxes	Total
Total foxes parasitized by *C. canis*	1	0	1
C. canis ♀ present	1	0	1
C. canis ♂ present	0	0	0
1968-69			
Total foxes parasitized by *C. canis*	0	1	1
C. canis ♀ present	0	1	1
C. canis ♂ present	0	0	0

Table 12. Infection rates of red foxes with *Cediopsylla simplex*.

	♂ foxes	♀ foxes	Total
1966-67			
Total foxes parasitized by *C. simplex*	4	4	8
C. simplex ♀ present	8	11	19
C. simplex ♂ present	1	1	2
1967-68			
Total foxes parasitized by *C. simplex*	4	6	10
C. simplex ♀ present	3	6	9
C. simplex ♂ present	2	5	7
1968-69			
Total foxes parasitized by *C. simplex*	4	10	14
C. simplex ♀ present	6	23	29
C. simplex ♂ present	3	10	13
3 Year Totals			
Total foxes parasitized by *C. simplex*	16	21	37
C. simplex ♀ present	17	40	57
C. simplex ♂ present	6	16	22

Table 13. Infection rates of red foxes with *Chaetopsylla lotus*.

	♂ foxes	♀ foxes	Total
1966-67			
Total foxes parasitized by *C. lotus*	6	4	10
C. lotus ♀ present	11	9	20
C. lotus ♂ present	3	1	4
1967-68			
Total foxes parasitized by *C. lotus*	7	4	11
C. lotus ♀ present	6	7	13
C. lotus ♂ present	2	1	3
1968-69			
Total foxes parasitized by *C. lotus*	4	8	12
C. lotus ♀ present	4	8	12
C. lotus ♂ present	1	5	6
3 Year Totals			
Total foxes parasitized by *C. lotus*	17	16	33
C. lotus ♀ present	21	24	45
C. lotus ♂ present	6	7	13

C. simplex tends to favor the female foxes as hosts.

Final analyses of the data concerns the young foxes collected. Flea transfer could not be proven by feeding these pups wild mice and rabbits. Young foxes may be immune to ectoparasites. Noble (1965) stated that there may be a metabolite that attracts a parasite to its host. It is possible that the young foxes had not yet produced this attractant. Another possibility for this lack of flea infestation could be an excitability factor. Fleas could have left the pups during the time of chase and capture.

CONCLUSIONS

The purpose of this research was to determine the rate of infection of the fleas infesting the red fox, and to ascertain the mode of transmission of these fleas. Rates of infection of the specific species of fleas found on the red fox was established. *Cediopsylla simplex* and *Chaetopsylla lotus* occurred on the red fox in greater numbers when compared to the infection rates of *E. wenmanni* and *C. canis*.

Further research could possibly prove that *C. simplex* does transfer from the rabbit to the fox during predation on the cottontail.

Young foxes were void of fleas at the time of capture, and there is no apparent transfer of these fleas from a food supply to the pups.

LITERATURE CITED

Besadny, C. 1964. The feasting fox. Wisconsin Conservation 29(6): 10-11.

Fichter, E. and R. Williams. 1967. Distribution and status of the red fox in Idaho. J. Mammalogy 48(2): 219-230.

Fox, I. 1940. Fleas of Eastern United States. The Iowa State College Press, Ames. 191 p.

Held, R. 1969. Personal Correspondence of the Author. Veterinarian at Animal Veterinary Hospital. Freeport, Illinois.

Hopwood, R. 1965. Elimination of fleas from an animal by aerosol insecticides applied in a closed environment. J. Amer. Vet. Med. Assoc. 146(10): 1115-1116.

Hubbard, C. 1968a. Field and laboratory technique, p. 28 to 37. In C. Hubbard, Fleas of Western North America. Hafner Publishing Co., Inc., New York.

Hubbard, C. 1968b. Family Pulicidae, p. 78. In C. Hubbard, Fleas of Western North America. Hafner Publishing Co., Inc., New York.

Hubbard, C. 1968c. Family Dolichopsyllidae, p. 88. In C. Hubbard, Fleas of Western North America. Hafner Publishing Co., Inc., New York.

Hubbard, C. 1968d. Family Pulicidae, p. 57 to 58. In C. Hubbard, Fleas of Western North America. Hafner Publishing Co., Inc., New York.

Ivens, V. 1969. Personal Correspondence of the Author. Veterinarian at the College of Veterinary Medicine. University of Illinois, Urbana.

Jackson, H. 1961. Family Canidae, p. 298 to 306. In H. Jackson, Mammals of Wisconsin. The University of Wisconsin Press, Madison.

Klimstra, W. and T. Scott. 1955. Red foxes and a declining prey population. Southern Illinois University Monograph Series no. 1. 123 p.

Layne, J. 1958. Records of fleas (Siphonaptera) from Illinois mammals. Chicago Academy of Sciences Natural History Miscellanea no. 162. 7 p.

Lewis, R.E. 1969. Personal Correspondence of the Author. Parasitologist at Iowa State University, Ames.

Mead-Briggs, A. 1964a. The reproductive biology of the rabbit flea Spilopsyllus cuniculi (Dale) and the dependence of this species upon the breeding of its host. J. Exptl. Biol. 41(2): 371-402.

Mead-Briggs, A. 1964b. Interchange of rabbit fleas. J. Animal Ecol. 33(1): 13-26.

Morse, M. and D. Balser. 1961. Fox calling as a hunting technique. Journal of Wildlife Management 25(2): 148-154.

Naaktgeboren, C. 1965. Die Fortpflanzung des Rotfuches, Vulpes vulpes (L.), mit besonderer Berucksichtigung von Schwangerschaft und geburt (English summary). Zool Anz 175(416): 235-262.

Noble, E. and G. Noble. 1965a. Life history and habits of fleas, p. 446. In Noble, E. and G. Noble, Parasitology - the biology of animal parasites. Lea and Febiger, Philadelphia.

Noble, E. and G. Noble. 1965b. Ecology of parasites, p. 577. In Noble, E. and G. Noble, Parasitology - the biology of animal parasites. Lea and Febiger, Philadelphia.

Osterholm, H. 1964. The significance of distance receptors in the feeding behavior of the fox Vulpes vulpes (L.) [English summary]. Acta Zool Fennica 106: 1-31.

Richards, S. and R. Hine. 1953. Wisconsin fox populations. Wisconsin Conser. Dept. Tech. Wildlife Bull., no. 6. 78 p.

Rothschild, M. 1964. Maturation and egg-laying of the rabbit flea (Spilopsyllus cuniculi Dale) induced by the external application of hydrocortisone. Nature 203(4941): 210-211.

Rothschild, M. 1966. Hormones of the vertebrate host controlling ovarian regression and copulation of the rabbit flea. Nature 211(5046): 261-266.

Scott, T. 1942. An investigation of food coactions of the northern plains red fox. Ph.D. Thesis. 221 p. Iowa State University, Ames.

Stark, H. 1962. Abandonment of disturbed hosts by their fleas. Pan Pacific Entomol. 38(4): 249-251.

Storm, G. 1965a. Movements and activities of foxes as determined by radio-tracking. J. Wildlife Management 29(1): 1-13.

Storm, G. 1965b. A wire ferret for use in studies of foxes and skunks. J. Wildlife Management 29(3): 625-626.

Verts, B. 1961. Observations of fleas (Siphonaptera) of some small mammals in Northwest Illinois. Amer. Midland Nat. 66(2): 471-476.

Wilson, N. 1966. A new host and range extension for Pulex simulans with a summary of published records (Siphonaptera : Pulicidae). Amer. Midland Nat. 75(1): 245-248.